PRACTICAL RECOMMENDATIONS FOR IMPROVING AIR POLLUTION POLICY IN RUSSIA

Air Pollution Working Group

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1. INTRODUCTION

1.1 Background

Air pollution from large stationary source polluters—industrial facilities and utilities—is recognized as a major environmental problem throughout the Newly Independent States of the former Soviet Union. Although data are incomplete, ambient concentrations of air pollutants in many Russian cities are believed to exceed international health standards on a routine basis. Evidence is also mounting that air pollution is associated with a significant share of Russia's very high mortality rates, as well as generating substantial morbidity and damage to ecosystems and buildings.

Since 1993, the Harvard Institute for International Development has been working with Russian environmental economists and policy specialists to develop practical, cost-effective solutions for managing air emissions from stationary source polluters.[1] In collaboration with the State Committee for Environmental Protection and regional and local environmental committees, HIID carried out detailed studies related to air pollution management in six Russian industrial cities.[2] These studies included:

- Analyses of the current Russian system of stationary source air pollution permits and charges.
- An evaluation of basic options to improve the current system.
- Quantitative assessments of air pollution health risks from major stationary sources in five cities.
- Quantitative evaluations of the cost-effectiveness of investment options for reducing emissions and health risks.

These studies were undertaken in collaboration with teams of Russian scientists, economists, and environmental policy specialists. An important capacity-building feature of the HIID project, this approach was designed to develop several teams of local specialists who can apply new research methods now and in the future to support Russian efforts to manage air pollution.[3] The HIID project also produced a number of reports presenting the methodology and results of the individual studies. These reports provide detailed, practical examples that can be readily applied in other cities in Russia. (See the Appendix for a complete list of these reports, which are available from HIID.)

The purpose of this paper is to synthesize the results and lessons learned in the HIID project studies into a set of priority recommendations. These recommendations, based on a combination of scientific and economic analyses and practical understanding of the experience and difficulties facing Russian environmental and health officials and enterprises, can be used in Russia by city, regional, and federal environmental officials for managing stationary source air pollution.

1.2 The Russian Air Pollution Management System

An explanation of the existing system of stationary source emissions permits and charges is needed as background to the recommendations. The core of the stationary source pollution management system in

[1] This work has been carried out as part of HIID's Environmental Economics and Policy Project under a Cooperative Agreement with the United States Agency for International Development. The HIID project also worked on several other issues in Russia, including forestry policy reform in the Russian Far East, environmental finance, natural resource taxation and valuation, and environmental liability.

[2] Volgograd, Novokuznetsk, Perm, Krasnouralsk, Angarsk, and Tula.

[3] By working collaboratively with teams of Russian and foreign specialists, HIID combined the best of both groups' experience while transferring to Russia new research methods, techniques, and general knowledge. Along with the analyses, the project provided training on risk assessment, cost-effectiveness analysis, and general environmental economics.

Russia is a set of annual, source-specific emission limits that can be established (at least in principle) for hundreds of pollutants.[4] These limits, which are fixed in pollution permits issued by Oblast Environmental Committees, include maximum emission rates (grams per second by source) and maximum emission limits (tons per year, called PDV in Russian).[5]

Based on various meteorological assumptions, maximum emission rates by source are set such that ambient 20-minute air quality standards (called PDKs in Russian) are never violated during the year when measured near ground level (1.5-2.5 meters from surface level) in a number of locations specified by the state standard.[6] These maximum emission rates assume full capacity utilization of the facility and full functioning of any pollution control equipment. In general, the annual emission limit (PDV) equals the maximum emission rate (grams per second) times the number of seconds in a year.[7]

Once enterprise emissions limits are determined using the PDK/PDV process described above, Russia then assesses enterprise pollution charges on the basis of tons of emissions per year. The basic structure of the system can be described as follows. A base charge of C is assessed on tons per year within the enterprise's emissions limit (less than or equal to PDV), and a higher "penalty" charge of 25*C is assessed on tons per year above the PDV limit. However, if a firm anticipates that its emissions will exceed its PDV limit, it can request and usually receive a temporary limit (called VSV) and pay a charge of 5*C on emissions over the PDV limit but under the VSV limit. Emissions above VSV are still assessed a charge of 25*C.[8]

Pollution charges are paid, at least in principle, into a system of federal, regional, and local environmental investment funds. However, due to the weak financial condition of many enterprises, pollution charge "credits" are often granted to enterprises to allow them to use their charge payments to finance environmental protection "investments," loosely defined. The actual necessity of granting these credits has never been examined, however, and appropriate criteria for granting them are not widely applied by environmental officials.

Emissions charges based on PDV and VSV limits can be assessed at the source level within each facility. Since large facilities often have hundreds of sources, however, in practice regional authorities often implement a facility-level "bubble policy," under which PDVs are summed across all sources within a facility. Charges for total reported emissions are then assessed in relation to this aggregated PDV, allowing some sources to exceed their individual PDVs as long as others are below theirs. This informal bubble approach was adopted mainly to ease the burden on environmental authorities and enterprises when calculating charges and to reduce total charges owed by enterprises.

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[4] The State Committee for Environmental Protection is the main federal body responsible for air pollution policy, with regional offices responsible for implementation and enforcement. For practical reasons, and due to severe financial constraints, the regional offices of the federal Committee often work closely with regional and city governments.

[5] Also see Kozeltsev and Markandya (1997) and Golub and Strukova (1995) for additional background on pollution charges and VHRAWG (1997) for additional discussion of setting emission limits.

[6] The basic Russian reference for this approach is OND-86 (1997). This approach is used for both relatively harmless and relatively hazardous pollutants, with the difference being 20-minute PDKs.

[7] To undertake such air quality modeling, there is a specific air modeling framework that is approved for use in Russia and is widely known and available in Russia. This framework does not attempt to model actual air quality conditions under general weather conditions; it is designed for worst-case modeling.

[8] In principle, payments of base (below PDV) charges are considered normal business expenses and thus paid out of before-tax profits. Payments for emissions above the PDV limit are considered penalties and are paid out of after-tax profits. In reality, the significance of the income tax treatment of pollution charges is irrelevant because of the unwieldy Russian income tax system.

1.3 Nature of the Recommendations

The recommendations are organized into three sections:

1. How can the existing system of pollution permits and charges be adjusted to: a) simplify its implementation, enforcement, and evaluation by city and regional environmental committees, enterprises, and others; b) reduce the costs to business of complying with the system; and c) increase understanding of the impacts of the system?

2. How can modern quantitative health risk assessment methods be used to: a) evaluate public health impacts of existing and expected future emission levels; b) incorporate chronic health effects into the process of setting annual emission limits (PDV and VSV); and c) focus regulatory attention and resources on stationary sources of greatest public health concern?

3. How can the results of risk assessments be combined with simple emissions control cost information to evaluate and prioritize options for reducing emissions and/or health risks?

HIID's work focused largely on current and continuing industrial operations, not on new projects under preparation. Industrial activities impose two general kinds of health risks on the community at large (as opposed to workers): risks from normal or expected emissions and risks from unexpected or accidental emissions. A wide variety of emissions are standard by-products of industrial processes, varying according to the type of industry and technology, the inputs used in the production process, and the equipment in place to reduce emissions. These "normal" emissions, which are more or less predictable, are transported through various environmental media (air, water, soil) and come into contact with humans, thereby creating some possibility of negative health impacts. In this situation, the risks to human health are determined by the level of human exposure and the impact of that exposure on human health. All HIID activities related to air pollution have focused on these normal or expected emissions.[9] The recommendations presented below are focused on policies for managing normal emissions from stationary sources.

It is emphasized here that these recommendations are designed to make improvements in air pollution policy (definition, implementation, and enforcement) within the existing legal and regulatory framework. The goal here is not to create new laws and attempt to identify the perfect air pollution management system for Russia. Overall restructuring of the current system—should restructuring be deemed necessary—is likely to take many years and significant financial and technical resources. Much can be achieved now, however, through relatively modest adjustments to the current system. The recommendations contained in this report are feasible at this time given available technical and financial resources and institutional capacity; are consistent with existing laws, regulations, and procedures; and can generate an immediate improvement in Russia's air pollution policies.

The recommendations presented below are consistent with Russia's Law on Environmental Protection (RSFSR Law No. 2060-1, adopted 19 December 1991, "On Protection of the Environment"), including:

- Article 3 on basic principles of environmental protection, including the priority to protect human life and health and prevent irreparable harm to human health. Article 3 also emphasizes that there should

[9] Industrial accidents lead to unexpectedly high levels of emissions, usually but not always for a relatively short period of time. These "accidental" emissions, such as explosions of chemical storage tanks, of course also create human health risks. For accidental emissions, environmental policy must address multiple questions of technology safety conditions (perhaps called technological risk assessment), as well as financial and criminal liability for accidents when they occur.

be an openness about this work, with close ties to public organizations and the general public in regard to environmental protection tasks.

- Article 6 identifying the government's authority to establish procedures for the development and approval of environmental standards for emissions and for setting fees for pollution.
- Article 7 stating that “duly authorized organs of the Russian Federation” are responsible for approving standards and regulations and issuing licenses (permits) for emissions.
- Articles 6, 7, 8, 9, and 12, which require a variety of organizations to provide essential environmental information to the public.[10]
- Article 25 (point 2) requiring that Russian standards should be improved over time based on scientific and technical advances as well as international standards.
- Article 27 stating that emission standards for chemicals are the responsibility of duly authorized environmental agencies of the Russian Federation.

According to these and other articles in the framework environmental protection law, the government and appropriate federal agencies are responsible for establishing the procedures to set air quality and emission standards and for approving the standards chosen. These procedures are supposed to be improved over time based on new scientific information and international standards. These articles provide the legal framework within which the recommendations below are intended to be implemented.

2. RECOMMENDATIONS

This section presents HIID’s recommendations for amending the Russian pollution management system for stationary sources using data, methods, and financial resources that are available in Russia now.[11]

2.1 Setting Stationary Source Emission Limits and Pollution Charge Rates

The recommendations below focus on improving the current system of setting annual stationary source pollution limits, determining pollution charge levels, and generating appropriate information for regulators and the public.

1. *Develop a two-tiered emission reporting and charge system*.

   In this system, the first tier would maintain the current system for all enterprises with emissions above some specified level. The second tier would involve a very simple reporting system for all enterprises with emissions below this level. The cut-off level between tiers could be defined in terms of, for example, X tons of total emissions of all pollutants and Y tons of emissions of specified pollutants per year.

   In HIID’s experience, total air emissions and risks from air emissions in urban areas tend to be highly concentrated among a small number of large polluters.[12] Developing formally a two-tiered system as recommended above would reduce the costs to smaller enterprises of complying with regulations (not necessarily pollution charge costs, but the costs of filling out forms, calculating payments, etc.) and

[10] The Russian Constitution (adopted on December 12, 1993 by Referendum) also states in Article 42 that everyone has a right to a favorable environment and reliable information on the state of the environment.

[11] In this paper, the recommendations are presented with only limited discussion to justify them. More complete justifications and supporting data and analysis can be found in the individual reports, through discussion with the Russian analysts involved in the work, or by contacting HIID.

[12] For example, in Volgograd, just two facilities out of 29 major polluters and hundreds of regulated enterprises account for some 85 percent of particulate mortality risks. Similar results were obtained in Novokuznetsk and the other cities studied.

would reduce the costs to regulatory agencies of implementing and enforcing the permit and charge system, making it easier for regulators to focus their attention on major polluters.

The cutoff point between tiers could be based only on total annual emissions (e.g. 100 tons) or on emissions of different categories of pollutants (e.g. less than 100 tons of "general" pollutants and less than 25 tons of some specified group of toxics such as carcinogens and/or category I toxics). Since charges from small (second tier) polluters make up only a small fraction of total charge revenues, eliminating charges entirely for the smaller polluters as part of a two-tiered system would have little impact on total revenues. Another option is to charge the small polluters a flat annual charge. Facilities would be moved into the higher tier automatically if and when production (and thus pollution) picked up.

2. *For large polluters (those regulated under the first tier of the two-tiered system), continue to use the basic three-level charge system (under-PDV, between PDV and VSV, and above-VSV).*

Given the financial constraints currently faced by many industrial facilities in Russia, it is probably necessary to keep the base charges modest at present. The penalty charge rates (above VSV and PDV) should be regarded as the main "incentive mechanism." To create a reasonable incentive for pollution abatement (but not a standard that is intended to be achieved at any cost) the penalty multiplier should be greatly increased, for example from 5 to 25 for above-VSV levels and from 25 to 100 for above-VSV or -PDV levels, as relevant. A practical, pre-announced, transparent plan for phasing this change into Russian policy would be needed.

3. *Regulate some form of total particulates (TSP) or PM10.*[13]

TSP can be defined as the sum of all solids emitted by the facility, which in Russia would include aerosols in the definition of TSP. In this case, the existing emission report 2TP-Air contains a position number 002 for "total solids." Total solids is an adequate definition of TSP and can be used now for the purpose of regulating particulates.[14]

4. *Incorporate longer time periods (i.e. annual exposures) into the existing PDV-setting approach.*

For managing acute health risks, it is appropriate to maintain the existing approach for defining maximum emissions (in grams per second) consistent with the 20-minute PDK. For managing chronic health risks, this approach could be adjusted slightly to rely on existing 24-hour PDKs (rather than the 20-minute PDKs), or an annual average PDK could be established for selected pollutants. Pollution charges would then be based on the PDV set using the 24-hour (or annual average) PDK. There are perhaps better ways to incorporate chronic health effects into the PDV-setting process, but they are also more complicated. The approach outlined here has the advantage of being compatible with existing practice in Russia and easily implemented.

The approach proposed above (using a PDV based on 24-hour PDKs), does not, however, consider explicitly human health effects, as population exposure is not considered. A complementary approach, perhaps starting with a small group of priority pollutants (TSP, carcinogens, Category I toxics), would require that enterprises themselves conduct a quantitative health risk assessment for their proposed PDV levels demonstrating that the levels of additional risk are within defined

[13]Russia does do some monitoring of ambient concentrations of particulates. It does not regulate particulate emissions as an aggregate.
[14] See the HIID report on the Volgograd risk assessment for a list of pollutants included in the definition of TSP for specific facilities.

acceptable levels. These issues of assessing chronic health risks are addressed in section 2.2 of this report.[15]

5. *Develop a formal, consistent, and publicly understood approach to granting pollution charge investment credits for pollution control expenditures*.

Applications for and approvals of credits should be available to the public. While data on this topic are difficult to assess at this point, it appears that in some locations the bulk of pollution charges are not now collected but instead remain in company hands as credits. It is not clear under the current system whether these credits are supporting useful pollution control activities or subverting the basic purpose of the pollution charge system.

6. *Require large (first-tier) polluters to report annual emissions data to the public (local community, shareholders, etc.) on an annual basis*.

Emissions reports for first-tier polluters, stating tons per year per pollutant by name and standardized pollutant code, as required for the permit and charge system, should be free to the public and widely disseminated in local newspapers, annual shareholder reports, and other readily available publications.[16] Implementing a public "right-to-know" information policy, which is consistent with the Russian Constitution and the Law on Environmental Protection, would greatly facilitate scientific analysis and citizen involvement in environmental policymaking. It would impose almost no additional burden on companies due to the existing reporting requirements of the permit and charge system.

7. *Develop unique codes for identifying all pollutants and organizing all emissions data, preferably drawing on those that are already internationally recognized*.

In emissions reports (2TP-Air), Russia does not currently have nationally uniform codes for all pollutants with PDKs. Developing consistent codes, preferably cross-referenced with international codes, would greatly facilitate data processing, analysis, and comparison across facilities and regions of Russia and well as comparison with other parts of the world.

2.2 Assessing Chronic Risks to Human Health from Stationary Sources

Health risk management can be defined as the process of assessing health risks, identifying and evaluating options for reducing these risks, choosing one or more of the options, and implementing the selected option(s). This section focuses on the assessment of the health risks generated by stationary source air emissions, the first step of the process above. The next section addresses the problem of identifying, evaluating, and selecting options for reducing the risks.

The current approach in Russia for regulating normal industrial emissions focuses mainly on acute health concerns generated by high ambient concentrations over short time periods. As a result, environmental authorities in Russia use 20-minute PDKs to guide their evaluation of short-term environmental conditions. Chronic health risks that result from longer periods of exposure to air pollutants, however, are

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[15] Russian environmental and health authorities would have to provide clear guidelines to enterprises and others on how to conduct such risk assessments. Draft guidelines that can be used by Russian environmental and health officials as a basis for developing official guidelines are already available.

[16] There remains the question of whether this information should be reported as an aggregate for a facility or by source. Given the large number of sources at major facilities, information aggregated to the facility level is probably the better approach (tons per year by facility).

also important and are not yet adequately addressed in Russian air policy. The recommendations below are designed to incorporate concerns for chronic health risks into Russian air policy.

1. *Extend the existing legal and regulatory framework to reflect concerns for chronic health risks in the PDV- and VSV-setting approach at the facility level.*

Because existing Russian policy focuses on short-term concentrations, no annual PDKs have been defined to allow evaluation of long-term health concerns.[17] There are no other accepted and practical methods that environmental authorities can use to take into account chronic health risks when determining acceptable emissions levels (PDVs) for industrial facilities.

As explained in recommendation 4 in section 2.1, a simple way to solve this problem is to use existing 24-hour PDKs as the benchmark for setting annual emission limits (i.e., determining allowable annual average and daily average g/s emission rates that satisfy 24-hour PDKs). Another approach would be to develop annual average PDKs directly, starting with a small set of priority pollutants (SO2, NOx, TSP or PM10). A third option would be to evaluate annual health risks from proposed emission levels for the set of priority pollutants directly, and then set emissions limits that are consistent with an allowable level of risk.

2. *Focus risk assessment efforts first on the issue of chronic (annual) mortality risks from particulates and in certain cases from carcinogens.*

An important obstacle to incorporating risk assessment methods into Russian environmental policy will be the many different types of risk assessments that can be done using different methods, data, and health criteria. While it is very important that diverse risk assessment methods be applied in Russia in the near future as part of the diffusion of risk assessment methodology, it is equally important to focus government resources first on the kinds of health risks that are likely to be a priority in Russian cities and to which risk assessment methods can be applied using existing and available data and air dispersion modeling capabilities.

Particulates are a good place to start because the scientific evidence on their health effects is fairly good (such as increased mortality from cardiovascular and respiratory disease), work in Russia on these effects is already underway, and the HIID studies offer a fairly simple approach to conducting risk assessments using existing data and modeling capabilities. Including carcinogens may also be appropriate because of health concerns from low levels of exposure over long periods of time. Since there are fewer than 30 chemicals defined as "known carcinogens, risk assessment methods can be applied to perhaps 30 or fewer pollutants. It is not necessary to conduct risk assessments of the hundreds of pollutants that are in principle regulated in Russia under the current system.

3. *Apply the standard four-step approach to quantitative health risk assessment (i.e. hazard identification, exposure assessment, dose-response assessment, and risk characterization).*

As implied by recommendation 2, the hazard identification stage should focus on some definition of particulates and on carcinogens. When considering for which enterprises some form of risk assessment may be required, a possible initial set would be all those enterprises identified as large or first-tier polluters (section 2.1 recommendation 1). Within the large polluter category, it may also be possible to exclude the smallest polluters, that as a group, account for 10 percent of total particulate

[17] There are 24-hour PDKs that in principle can be used for evaluating longer time periods. Most 24-hour PDKs, with the exception of vinyl chloride and B(a)P, were established without considering carcinogenic effects. Even though there are 24-hour PDKs, emission limits (PDVs) are set solely on the basis of 20-minute PDKs.

emissions or total carcinogen emissions. In HIID experience in large industrial cities in Russia, it is probably appropriate to implement a risk assessment requirement initially only for perhaps the largest ten polluters in any one city, as these enterprises typically account for as much as 90 percent of total emissions.

It would not be wise for Russia to invest its own limited resources in developing new slope-factors for carcinogens at this time. Dose-response assessment for carcinogens should rely on existing, internationally accepted slope factors. Dose-response calculations for particulates should follow the basic approach outlined in HIID's report on the Volgograd risk assessment.[18] With epidemiological studies already underway in Russia on the correlation between particulate concentrations in air and mortality, it is likely that new Russia-specific information on the relationship between particulates and mortality will be available in the not-too-distant future.

4. *Make explicit the link between health risks and the facilities that generate the risks to permit subsequent identification of cost-effective policy options for reducing risks*.

A direct link between health risks and the contributors to these risks is necessary to make the results of the risk assessment immediately relevant to the current environmental policy debate in Russian cities. While measured ambient air concentration data can be used to conduct a basic risk assessment, this approach does not identify the specific sources of the risk. Emissions reports from stationary source air polluters can provide the core data needed to assess risks from stationary sources, and the links between individual polluters and the health risks they create can be made by modeling the dispersion of enterprises' air emissions throughout the city.[19]

5. *Continue to use the existing air dispersion modeling approach specified in OND-86 and related documents, and use the 'weighting-factor' approach to convert short time-period estimated concentrations into an estimated annual average concentrations*.

There is not one correct approach for converting short time-period estimates of air concentrations into annual average concentrations. One approach was developed for the HIID risk assessments in five Russian cities. Another approach is to run an existing dispersion model normalized to a one gram/second emission rate (either by source or aggregated to the facility level as in the Volgograd risk assessment) and then multiply the resulting estimated air concentrations by an estimate of the annual average emission rate in grams per second (which can be calculated directly from reported annual emissions levels in tons per year). Until the technical capacity to model air dispersion over longer time periods (i.e. annual average air concentrations) is widely available in Russia, either of these approaches will provide the results needed to carry out a risk assessment.

6. *Move quickly to disseminate the ability to use air dispersion modeling programs that estimate air concentrations over longer periods of time (e.g. annual averages)*.

Since many existing air dispersion models and computer programs can perform such analysis, including models already translated into Russian, improving local modeling methods need not be a complicated or time-consuming process. There is already experience in Russia in using such models. A major constraint for implementing better models will be the accessibility and quality of the

[18] We emphasize the word "approach" here because a number of assumptions are needed to make the link between ambient TSP concentrations and annual additional mortality impacts. See HIID's reports on Volgograd for further discussion of this approach.

[19] When this recommendation is followed, it will then be possible to assess the additional risk created in a particular region when a company is allowed a VSV level that is higher than its PDV level.

meteorological information that is currently generated in Russia. A useful project for foreign assistance financing would be to support the creation of a meteorological modeling data base (wind rose, stability classes, etc.), beginning with major cities and industrial areas in Russia, to facilitate better air dispersion modeling. In some locations, it may be necessary to establish new, reliable meteorological monitoring stations for state-of-the-art air quality modeling.

7. *Report all assumptions and calculations used in conducting risk assessments in a clear, replicable, and policy-relevant fashion*.

While perhaps an obvious suggestion, it is clear that this recommendation has not been a common practice. HIID's Volgograd risk assessment report provides one example of how to present concisely assumptions and results of a risk assessment for carcinogens and particulates.

2.3 Evaluating the Cost-Effectiveness of Options for Reducing Emissions and Health Risks

The principle underlying cost-effectiveness analysis is simple: once a desired outcome (e.g. reduction of emissions, reduction of health risks) has been selected, one should spend the least amount of money possible to achieve it. This section provides a set of recommendations for using cost-effectiveness analysis to identify, evaluate, and prioritize options for reducing the health risks that are assessed and evaluated as part of a risk assessment.

1. *Use either emissions levels or health risk levels as a baseline from which to evaluate emissions reduction options*.

It is crucial to have a starting point from which to evaluate emission reduction options, whether in terms of emissions or health risks. If a risk assessment like that described in section 2.2 has been carried out, it will provide the baseline health risks against which changes in health risk resulting from an emissions reduction project can be measured. When the results of a risk assessment are not available and are not expected to become available soon, gross emission levels (of SO2, NOx, PM10, etc.) or "toxicity-weighted" emission levels can be used for the cost-effectiveness analysis.

Using gross emissions and/or toxicity-weighted emissions may be useful even when risk assessment results are available, because risk assessments do not always provide comparable results for different pollutants.[20] For example, while it may be reasonable to compare cancer mortality risks from some pollutants to cardiovascular mortality risks from other pollutants, it is very hard to compare mortality risks to morbidity risks (e.g. child blood lead levels leading to reduced IQ). For many pollutants, health criteria are defined in terms of some average estimated dose (d) and a reference dose (RfD). If a Hazard Index, defined here as HI = d/RfD, is greater than 1, then there is assumed to be some level of concern (risk). This HI approach is adequate when risk management is concerned with a single pollutant. The HI approach is not adequate when several pollutants must be addressed at the same time, as is usually the case for city and regional environmental authorities.

2. *Use information already being generated to identify a set of relevant investment and other options for reducing emissions and/or health risks*.

Identifying options for reducing emissions (and thereby reducing health risks), whether investment options or policy changes, is probably the most important and difficult part of any cost-effectiveness analysis. However, since many enterprises have already begun looking to outside sources of funding

[20] Of course this raises the question of toxicity weights. One option is to use 1/ PDK for each pollutant as a weight for aggregation, where PDK is the 24-hour ambient standard.

for financing environmental projects (city, regional and federal environmental funds; city budgets; pollution charge credits; international grant and loan agencies), it is HIID's experience that considerable information about options for reducing emissions is already being generated in Russia. Cost-effectiveness analysis just uses this information in a new way to provide additional insights into the impacts of the proposed activities.

At a minimum, information about an investment project for reducing emissions or health risks should include, in constant prices:

a. Capital expenditures in each year during construction, which in Russia are defined as "equipment and civil erection" (K_i, where i represents year).
b. Project construction time (m years) and expected operating life of project (n years).
c. Annual operating and maintenance (O&M) costs of the project (C_i).[21]
d. Emissions reductions (tons per year of specific pollutants) each year during the life of the project (dE).[22]

3. *Select environmental criteria for which adequate information is available.*

When one pollutant is of concern, such as tons per year of SO2, the project information listed in recommendation 2 is adequate for conducting a cost-effectiveness analysis. If toxicity-weighted emissions are to be used, then the change in toxicity-weighted emissions resulting from the project must be calculated. If health risks are to be used, then the change in health risks from implementing the project must be estimated. When a baseline risk assessment is available, the risk characterization can be redone using the altered emissions levels resulting from implementation of the project.

4. *Use standard project finance criteria to calculate the present value of costs of the project(s) and prioritize options in terms of annualized present value of costs per change in environmental impact.*

a. Calculate the present value of costs.

To generate practical guidance for policy makers, project costs must be defined in a way that allows multiple projects to be compared in equivalent terms and project costs to be compared to project benefits (e.g. annual emission reductions, annual risk reductions). The project information listed under recommendation 2 above is often available, although project life is rarely specified directly in project documents. When this information is available, the *Present Value of Costs* (PVC) of each project can be defined as:

$$PVC = \sum_{i=1}^{m} K_i \left(\frac{1}{1+r_i}\right)^{i-1} + \sum_{i=m}^{n} C_i \left(\frac{1}{1+r_i}\right)^{i} \qquad (1)$$

[21] It is often the case that construction time, operating life of the project, and annual O&M costs are not clearly identified in project definition documents. They should be.

[22] Of course, in some cases, risk reduction does not necessarily imply emission reductions by facilities. For options such as moving the location of agricultural activities, housing, schools, etc., similar information is needed to estimate project costs.

where all the notation in equation (1) is defined under recommendation 2 except r_i, which equals the annual interest rate used for project financial evaluation (next best alternative use for this money).[23] In equation (1), it is assumed that capital costs K_i are paid at the beginning of each period during the construction period 1...m, while O&M costs C_i are paid at the end of each period during the operating period m...n.

In a simple case where all capital costs are paid at the beginning of period 1, operating costs C_i are constant, are equal to C in real terms, and are paid at the end of each of 10 periods, then equation (1) can be simplified to:

$$PVC = K_1 + C \sum_{i=1}^{10} \left(\frac{1}{1+r} \right)^i = K_1 + Z(r,10)\ C \tag{2}$$

For example, if C=10, r=10%, and there are 10 periods, then Z(10%,10) = 6.145.[24]

b. Determine the annualized present value of costs per change in environmental impact (change in emissions of specific pollutant, change in toxicity weighted emissions, and/or change in health risks).

Assuming for example that each project yields a change in risk dR_i during the operating period (periods m to n), a general 'cost-effectiveness' criteria P can be defined as:

$$P = \frac{PVC}{\sum_{i=m}^{n} dR_i \left(\frac{1}{1+d} \right)^i} \tag{3}$$

where d is a 'discount' factor used to translate changes in risk across different periods into a common denominator in period one. With dR_i representing changes in mortality risks, the cost-effectiveness criteria P can be interpreted as the cost-per-life saved.

While choosing an interest rate to discount costs across periods is not too difficult, choosing a discount rate to compare risk changes across different time periods is difficult. While it is not conceptually clear if risks should be discounted, empirical research from the U.S. suggests that people do make such discounting considerations in their opinions of the benefits of risk reduction activities. For initial practical analysis in Russia, it is acceptable to begin by choosing d = 0.

c. Use the "average price" of each project as a basis for prioritizing projects and developing a least-cost reduction schedule.

When multiple projects to reduce health risks are being evaluated, it is possible to rank projects according to average price P^i and develop a least-cost emission and risk reduction schedule. The schedule provides decision makers (company executives, ecological committees, environmental

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[23] If capital costs C_i and O&M costs K_i for all periods are defined in terms of, for example, 1996 rubles, then they are defined in real terms that do not include inflationary changes that may occur in the future.

[24] The function Z can be calculated easily using standard spreadsheet computer programs such as Excel or QuatroPro. (For example, @pv(1,10%,10) = 6.145.)

funds) with information on a logical implementation sequence for projects, given some reasonable budget for air management investments.

5. *For the near-term, apply cost-effectiveness analysis to major pollution reduction options without overdue concern for valuation of benefits*.

For any one project, the average price or cost P^i of each unit reduction in emissions and/or risks can also be compared to the expected benefits of a unit reduction. For example, in HIID's analysis in Volgograd, costs to reduce mortality risks in the city by one death per year ranged from 0.45 million rubles ($78) to 39 million rubles ($6,724). Once an estimate of costs per unit reduction is in hand, it is possible to gauge whether this is a reasonable price to pay to reduce mortality risks.

While policy makers in different cities may answer this question differently, HIID's analysis suggests that an extremely conservative (low) estimate of the Value of a Statistical Life in Russia is in the range of 171 million rubles ($29,483)[25]. Given the very modest cost of risk reduction options at the lower end of the least-cost reduction schedule (<$100 per life saved per year), it is not necessary to undertake the more complicated and controversial task of valuing the benefits of lower end pollution reduction projects in the immediate future.

3. CONCLUSIONS

It is not realistic to expect that the answers to all air pollution management problems in Russia can be found by revising the pollution permit and charge system or can be reduced to risk assessment followed by cost-effectiveness analysis. Some aspects of the current air pollution crisis are likely to require more complicated, more expensive, and longer-term solutions than those proposed in the recommendations above. The recommendations in this paper do, however, offer practical, near-term responses to many of Russia's stationary source pollution problems. All of the recommendations are consistent with the existing Russian legal framework for air pollution management. All can be implemented immediately, using existing technical, institutional, and financial resources. Despite their modest aspirations—they are intended to revise the existing system, not replace it—implementing these recommendations is likely to lead to an improvement in air quality in Russia's industrial centers, with a commensurate decline in air pollution health risks, and to reduced costs to government and industry.

The recommendations may also offer guidance to foreign assistance agencies seeking to support practical measures for improving air pollution management in Russia. Though all the recommendations are feasible using local resources, some would be much more readily achieved with outside financial assistance. Foreign assistance projects that are suggested by the recommendations include the creation of a meteorological modeling data base and the establishment of new, reliable meteorological monitoring stations for state-of-the-art air quality modeling; technical assistance in designing the two-tiered pollution charge system; assistance in disseminating air dispersion models that estimate air concentrations over long periods of time; and training for enterprise and government officials on the documentation of prospective investment projects and on cost-effectiveness analysis.

[25] Note that this estimate of the benefits of pollution reduction is only for mortality; it would increase were the benefits of reduced morbidity, ecosystem damage, and building damage included.